Ground-Water Modeling with Analytic Elements: cultivating understanding of ground water systems Part I, II

6/7/01

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Ground-Water Modeling with Analytic Elements:

cultivating *understanding* of ground water systems

Part I, II

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Outline

I. Introduction

II. AEM Basics

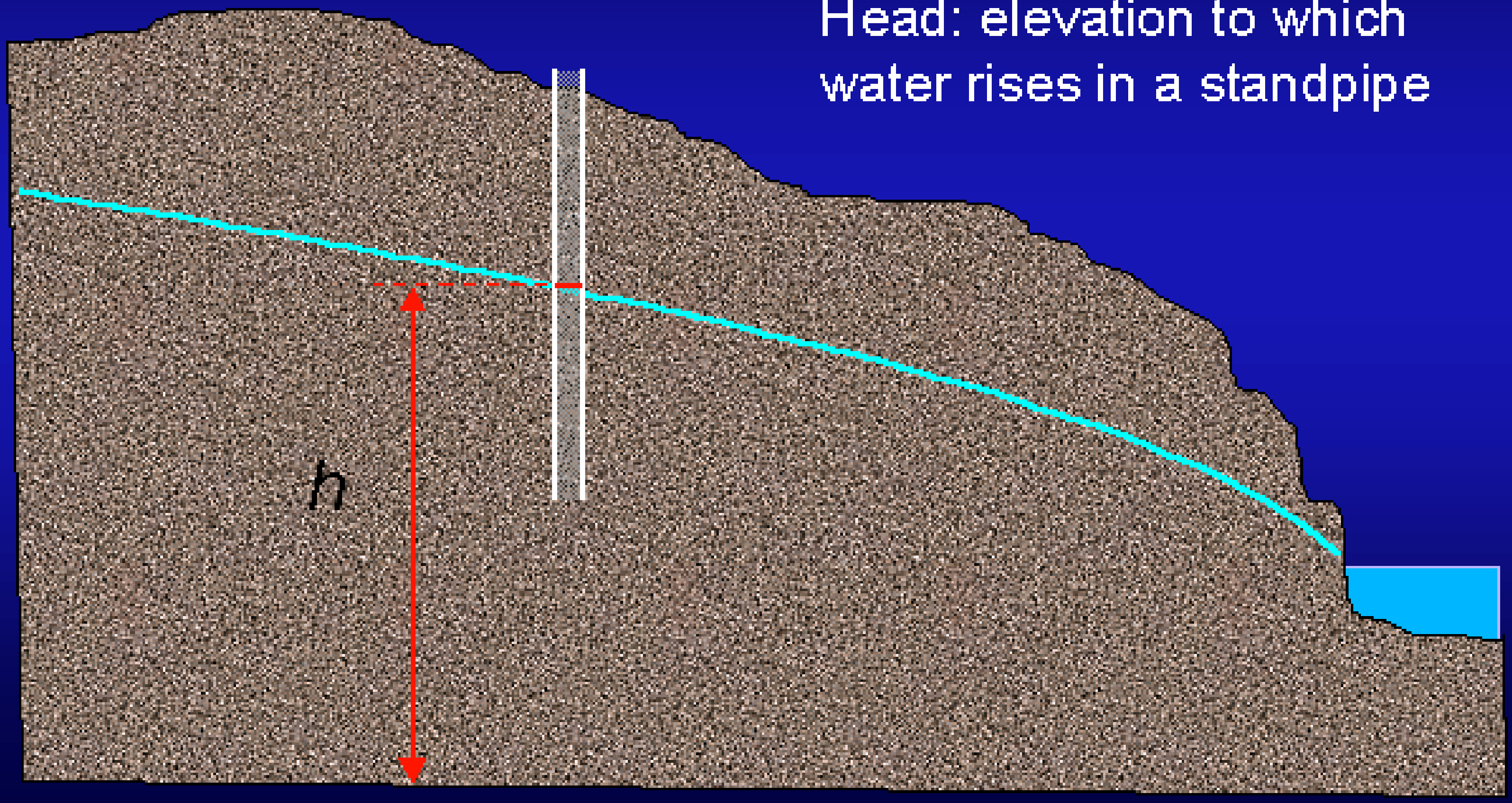
III. AEM Applications

IV. Future

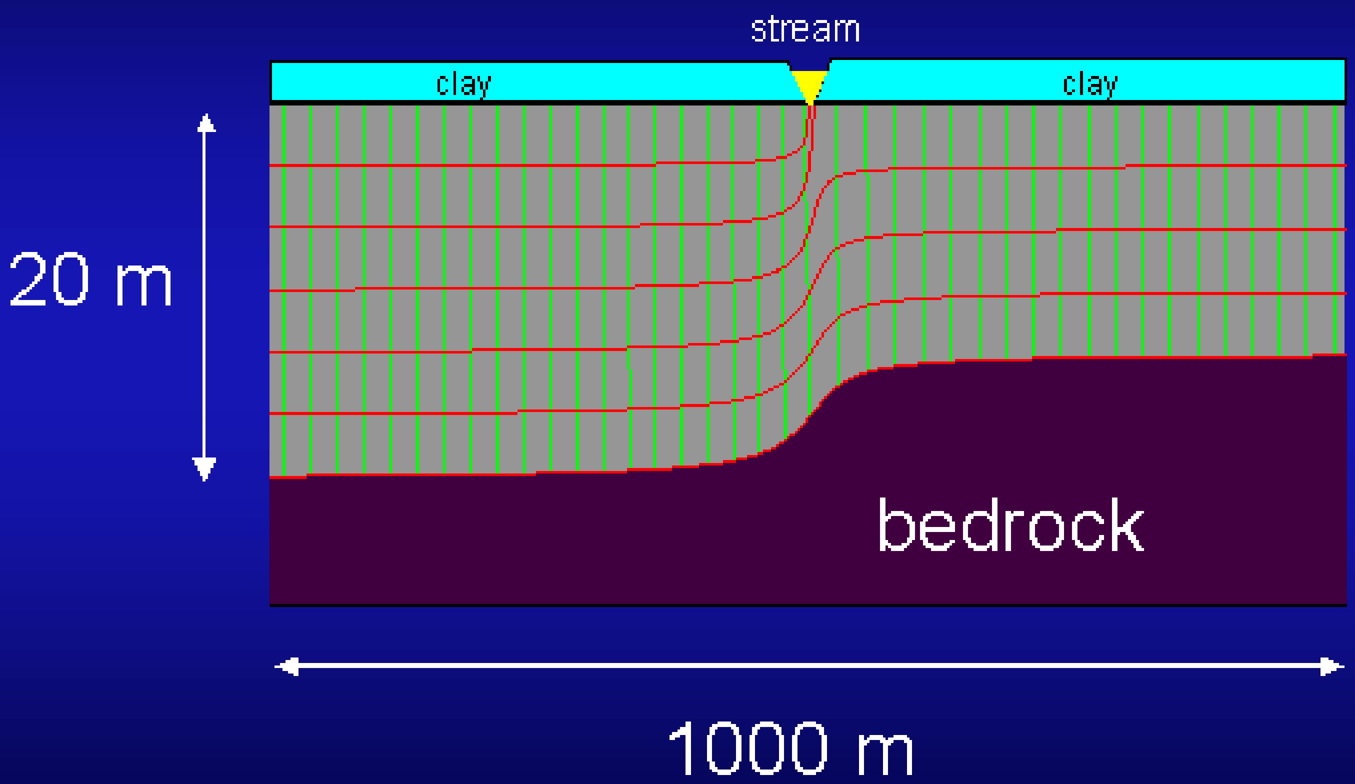
II. AEM Basics

Groundwater Mechanics

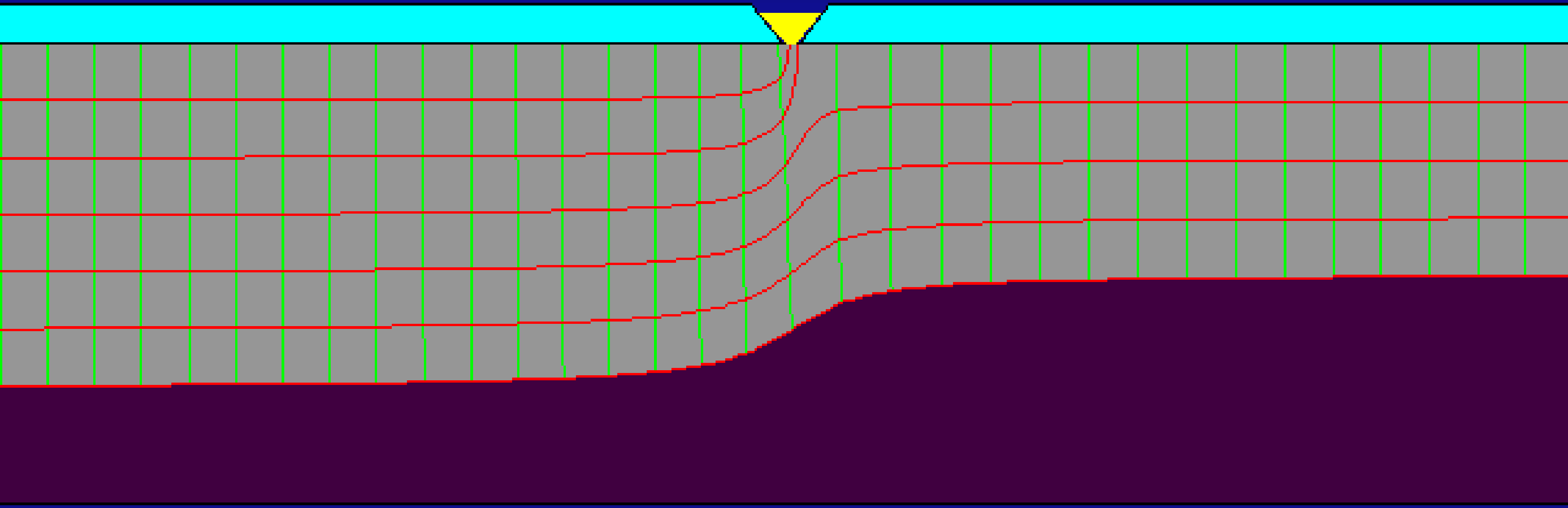
Head: elevation to which water rises in a standpipe



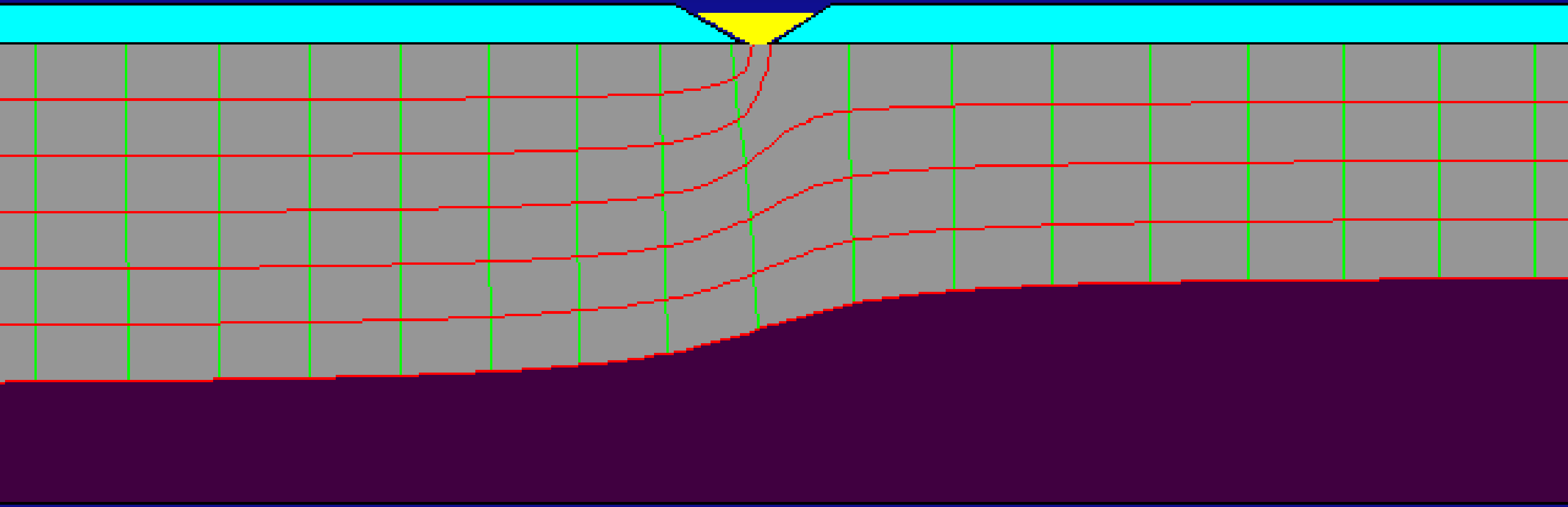
Flow to a stream



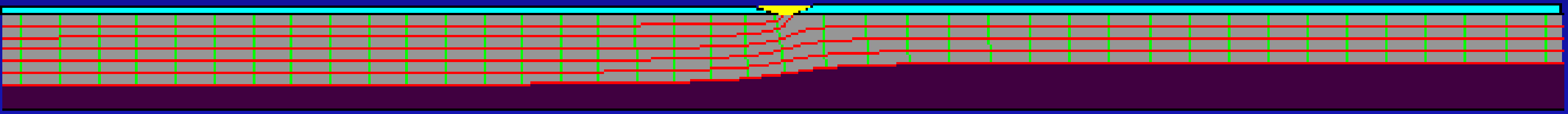
Stretch domain



Until scales are equal



Plotted to scale:
Flow is essentially horizontal



Dupuit-Forchheimer Flow

Neglect resistance to vertical flow

Thus: heads are constant in the vertical

Advantage: You get rid of one dimension in the differential equation

Mathematical formulation

- Darcy's law

$$q_x = -k \frac{\partial h}{dx} \quad q_y = -k \frac{\partial h}{dy}$$

- Continuity of vertically integrated flow

$$\frac{\partial}{\partial x}\left(kh \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y}\left(kh \frac{\partial h}{\partial y} \right) = -N$$

Introduce Discharge Potential

$$\boxed{\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial y^2} = -N}$$

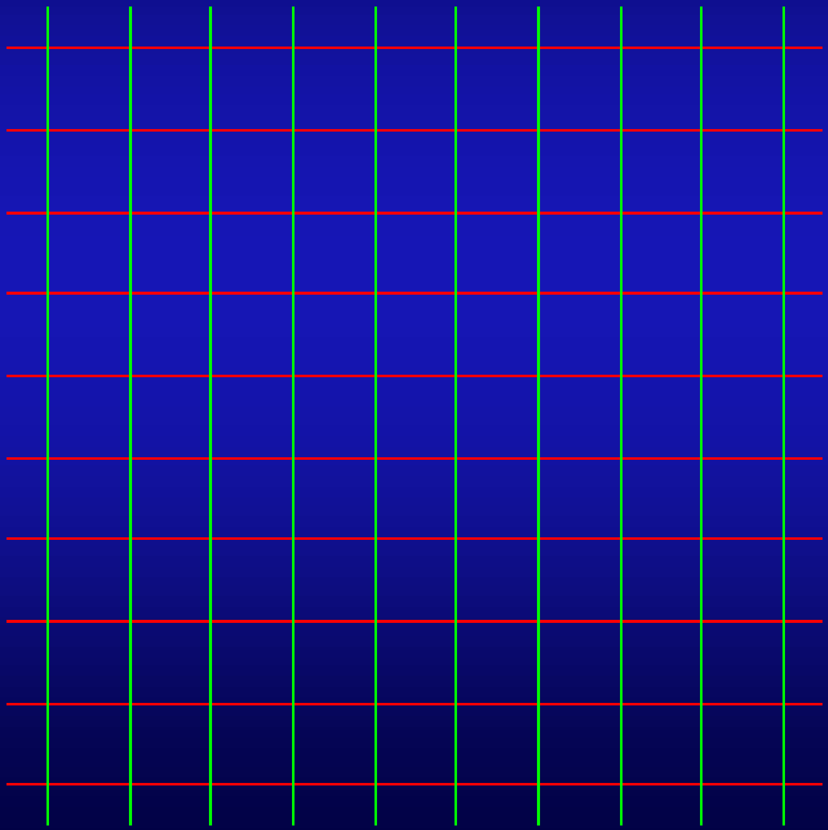
Confined flow: $\Phi = kHh$

Unconfined flow: $\Phi = \frac{1}{2} kh^2$

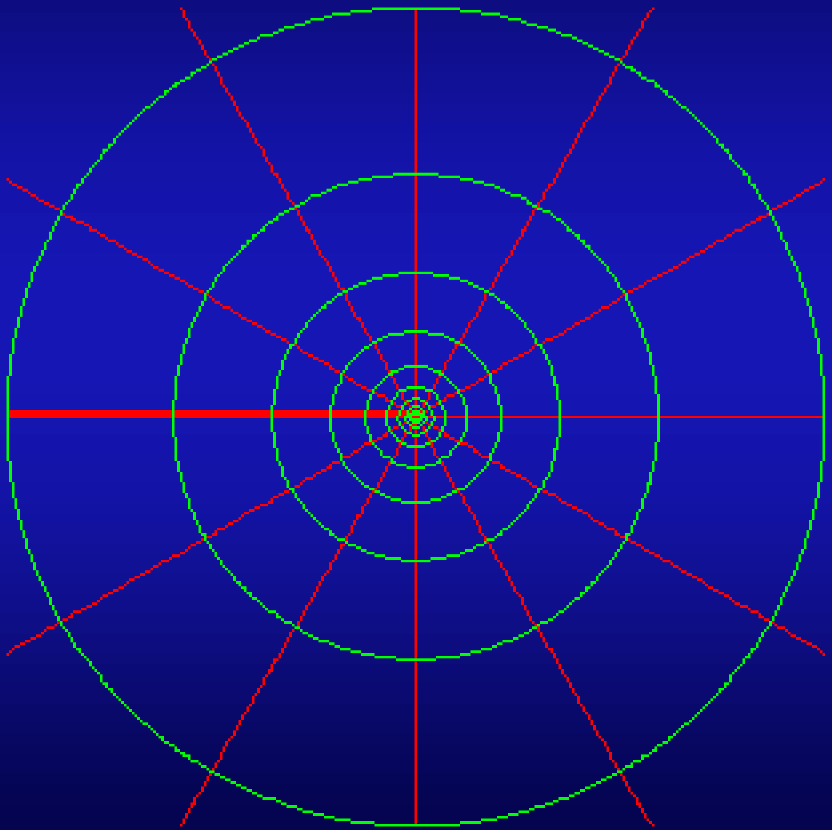
Analytic Elements 101

- Based on the superposition of analytic functions
- Each analytic function is an analytic element
- Each analytic element represents a hydrogeologic feature in the aquifer
- Each element has degrees of freedom, so that different boundary conditions can be met
- Initially developed by Otto Strack

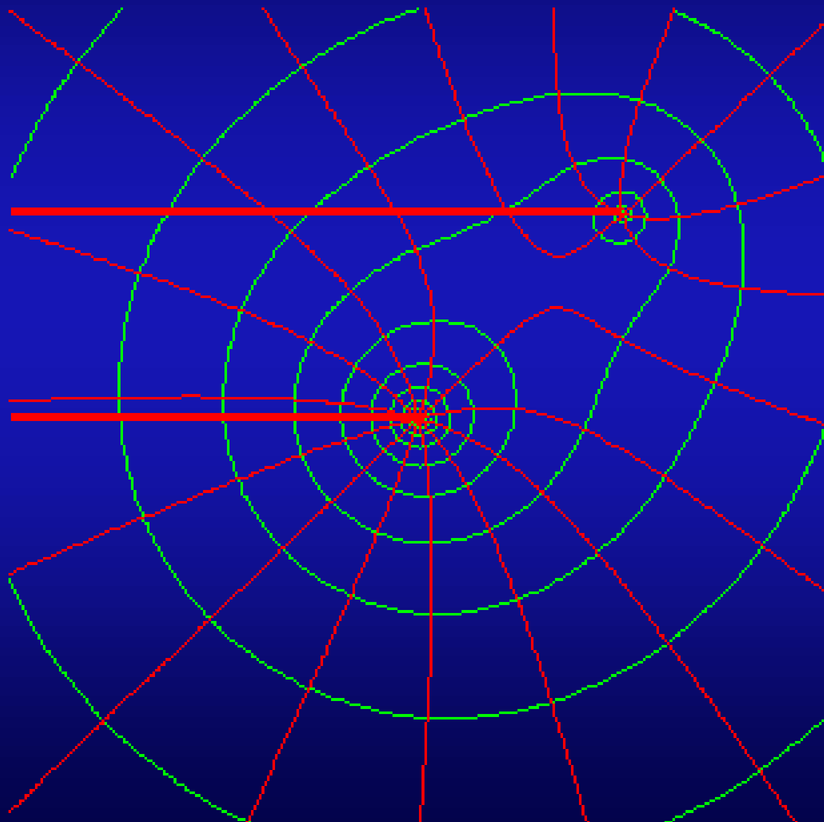
Uniform Flow



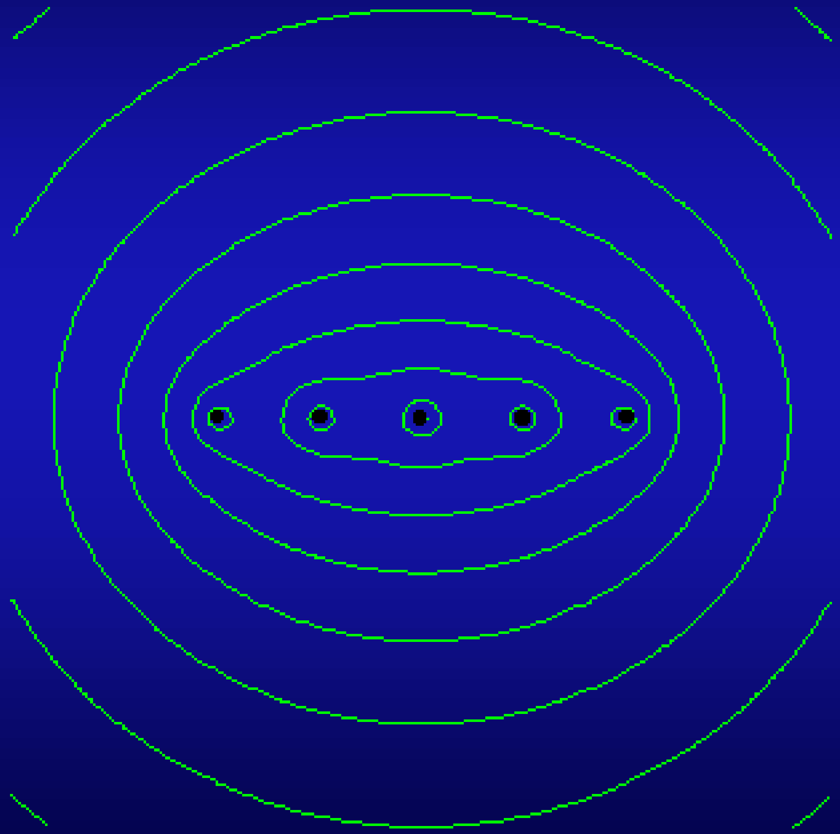
One Well



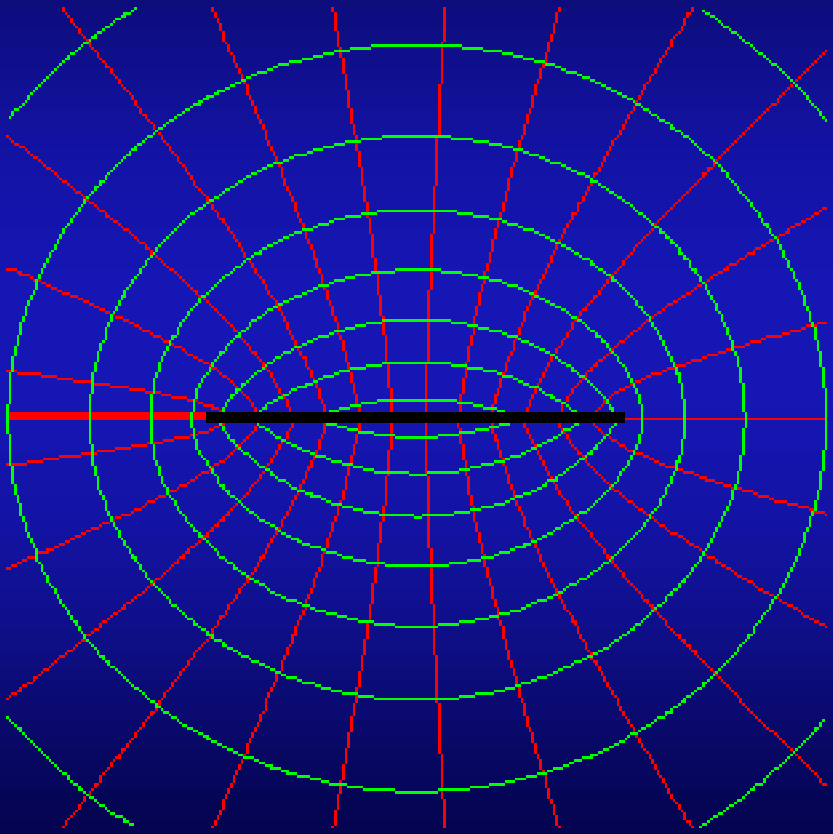
Two Wells



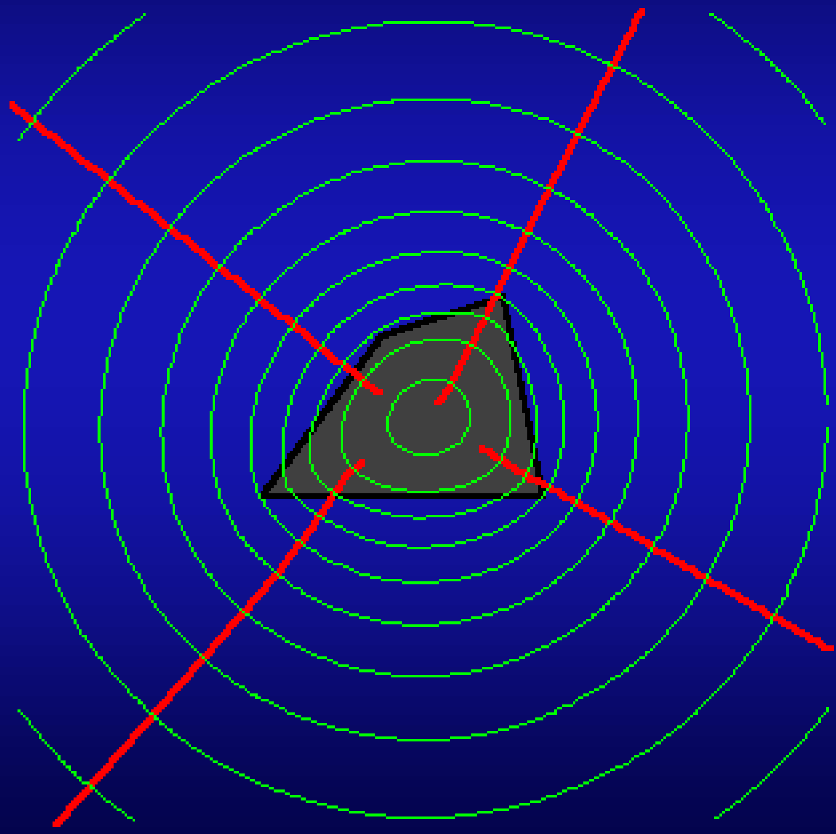
Five Wells in a Row



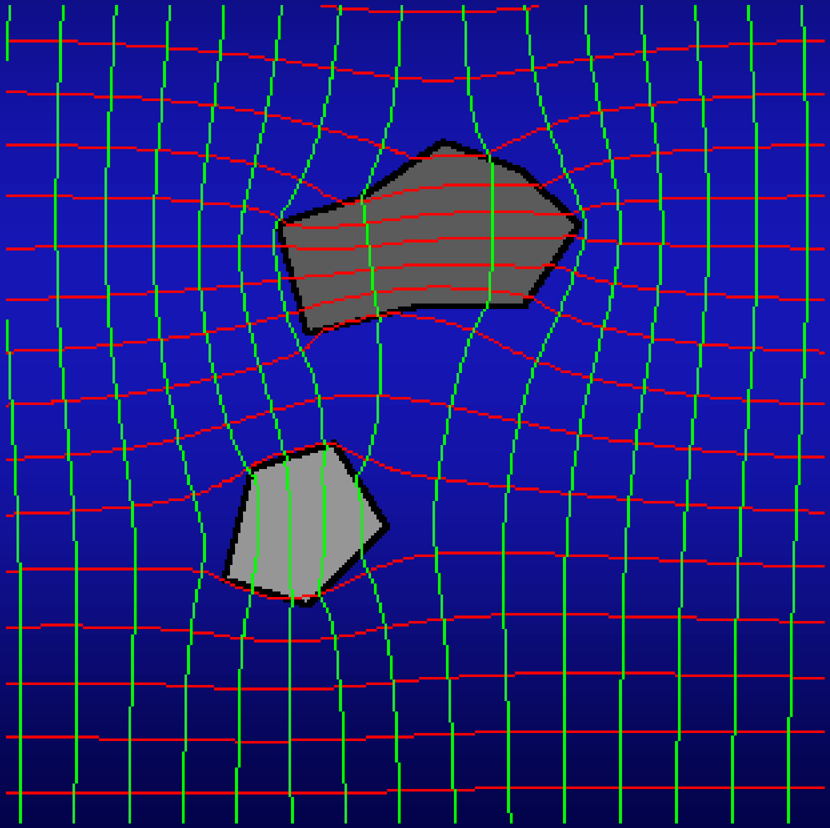
Line-sink



Area-sink



Inhomogeneity



Advantages of AEM over Discrete Numerical Models

- No need for artificial boundaries
- More accurate, because solution is analytic (no discretization)
- Insight gained because every analytic element represents a hydrogeologic feature